UNIVERSITI PUTRA MALAYSIA

# THE WEAR PATTERN OF ROUTER CUTTER MATERIAL BETWEEN HIGH SPEED STEEL AND SOLID TUNGSTEN CARBIDE IN CUTTING RUBBERWOOD MEDIUM DENSITY FIBERBOARD

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The wear pattern of router cutter material between High speed steel and Solid tungsten carbide in cutting rubberwood Medium Density Fiberboard

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Specially dedicated to:

My beloved Father and Mother, my wife and daughter and all my family members for their support through my work and study, may Allah bless U all

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AVG | Average |
| CNC | Computer Numerical Control |
| EW | Edge Wear |
| EL | Actual cutting length |
| FRIM | Forest Research Institute of Malaysia |
| HSS | High Speed Steel |
| MC | Moisture Content |
| MDF | Medium Density Fibreboard |
| STC | Solid Tungsten Carbide |
| RPM | Rotation Per Minute |
| UF | Urea Formaldehyde |
| m | meter |
| mm | Millimeter |
| $\alpha$ | Rake angle |
| $\beta$ | Wedge angle |
| $\gamma$ | Clearance angle |
| r | Local edges radius |
| e | Eccentricity |
| $F_x$ | Cutting force |
| $F_y$ | Feed force |
| WA | Wear A |
| WB | Wear B |

## ABSTRACT

In order to study the wear pattern of router cutter material between High speed steel and Solid tungsten carbide in cutting rubberwood MDF two type of router cutter material (HSS and STC) were employed. The solid tungsten carbide showed the longest working life (twice the cutting distance compare to high speed steel), while the high speed steel retained its usefulness for only a short distance of cutting (tool life). It was confirmed that the steel wore faster than tungsten. The observation show that solid tungsten carbide is more suitable because it wear only a few micron compared to high speed steel in cutting rubberwood MDF but high speed steel can be sharpened to improve it's performance but at an extra cost and time. It is more economic and productive. Solid tungsten carbide is the better alternative as there are many constrained.

# CHAPTER I

## 1.0 INTRODUCTION

### 1.1 Background

The router is one of the latest and most indispensable machines in the furniture making process. Many operations can be performed. For example it is used for making fine lines and grooves for veneer inlaying. Other uses include light shaping cuts, shallow boring and mortising, dovetailing, fluting and moulding. For pierced work, it completely eliminates the need of jigsaw since it produces finished shaped edges at one cut. On the larger machines, rope moldings, spiral turnings and rosettes are produced.

Ideally, materials used in cutting tools must have the following characteristics:

i. Hardness

ii. Mechanical resistance to bending and compression

iii. Resistance to abrasion

iv. Resistance to high temperature

v. Resistance to chemical reaction.

The above characteristics are needed to minimize cutting tool wear. The wear of cutting tool is generally, the process, which make a useable tool unfit for continued use. The wear of cutting edges can be thought of as occurring at one of two distinct rates:

i. A large scale (relative of the size of the tool-work contact region) fracturing the tool edge or catasthropic.

ii. More gradual wearing where microscopic particles are worn away.

The catastrophic type is usually associated with poor tool of process design or operating procedures and is easily avoidable. On the other hand, gradual wear of cutting tools at the microscopic level is normally unavoidable, (Klamecki, 1979).

Tool wear has a direct bearing on the quality of the finished product, (St. Laurent, 1970). Thus it incur cost when the product is rejected due to poor quality. The replacements of the worn cutter tool either by regrinding of substitution of a new one also represent a necessary cost.

The machining of dry wood and reconstituted wood products such as medium density fiberboard (MDF) expose the tool edge to high temperatures and pressures in the cutting zone. As fiberboard is machined the tool temperature increases dramatically and the MDF breaks down thermally, which introduces numerous chemicals into the cutting environment. Abrasion is one of the factors. The machining of MDF may produce even more decomposition products that can adversely affect tool wear. MDF contains wood as well as binders such as urea-formaldehyde resin, catalysts, wax, and possibly other additives. (Stewart, 1991).

Above all, the performance of various router bit may be considered the most important thing to be observed. The study of various router bit is brought out in conversation because of its cost and performance due to moulding operation in wood based panel, especially in routing or cutting the Rubberwood Medium Density Fiberboard (MDF).

Commonly used cutting tool materials are High Carbon Steel alloy, High Speed Steel (HSS), Stellite and Tungsten Carbide. However, there are other materials that are as hard or harder than Tungsten Carbide such as Synthetic Diamond Cermet, Ceramic and Cubic Boron Nitride.

However, these materials originally developed by the General Electric in 1950s are mainly used for machining like ferrous alloy, fiberglass, graphite, high temperature alloy and other abrasive materials, (Venkatesh, et al., 1982). So far, only Synthetic Diamond had made an inroad as a wood-cutting-tool material (Anon, 1988).

## 1.2 Tooling for shaping profiles

Routers are used mainly for shaping simple profiles. Blunt tools will give rise to chipping and burn marks on the surface of the workpiece. This is because blunt tools generate a lot of friction and heat during routing. Tools must be sharpened before starting work and not changed or sharpened during work. This is because a sharpened tool has a slightly different outline from an unsharpened one and will effect the shape of the workpiece being machine.

In this study, two router bits cutting tools are used:

a. High Speed Steel (HSS).

b. Solid Tungsten Carbide (STC).

**1.3 High speed steel**

Blunting is a problem more important with the cutting of wood materials which are densified or which contain hardened artificial resins (Kollmann and Cote, 1984).

Pahlitzsch and Jostmeier (1964a) investigated the wear properties of hard metals and high-speed tools in moulding two different parts of particleboard. It appeared that the wood species of which the particleboard was made influenced the blunting effect. After stock is manufactured into a relatively soft tool, HSS can be uniformly hardened and subsequently tempered.

The most important property of all HSS is its retention of hardness at elevated temperatures because high temperature exists at the tool edge and accelerates tool wears, (Stewart, et al., 1992).

Stewart (1991) conducted a study on seven High speed steel treated at two hardness levels were applied in a tool wear test with medium density fiberboard. Each

High speed steel and heat treatment combination was replicated nine times. The parallel and normal tool force components were the wear indexes after 7,600 inches of MDF had been cut. A number of High-speed steels (HSS) and heat treatment combinations can be applied to wood machining.

**1.4 Solid tungsten carbide**

Solid tungsten carbide cutters have the durability of tungsten carbide tipped but are less prone to failure. For this reason they are safer as the tips cannot become detached and fly off. They also can be ground to produce a far superior plunge cutting action than is possible with tipped cutter. They can be used for application where cutting temperature are likely to be unavoidably higher than recommended for tipped cutters.

Wood cutting tools are usually required to have not only a higher hardness, i.e. a higher wear resistance, but also sufficient toughness for withstanding the severe conditions of woodcutting (Sugihara, 1961a,b).

The most common carbide materials used in woodcutting are tungsten carbide-cobalt grades, namely straight tungsten carbide, with a relatively high toughness. However, little attention has been paid to the most suitable carbide grades for woodcutting although it is an important problem to be solved (Sugihara, et al., 1972).

There have been only a few comprehensive studies on the wear and working life of a carbide tipped cutter, although it is widely used for may woodworking processes. It was pointed out that the hardness of carbide cutter tip and the cutting velocity affected the wear of cutter tip; the softer the cutter tips and the higher the cutting speed, the greater is the wear of the tips (Kinoshita, 1958; Yamaguchi and Aoyama, 1962; Stefaniak, 1971; Koga and Nanasawa, 1973 a; b).

**1.5 Medium Density Fiberboard (MDF)**

Medium density fiberboard (MDF) is a wood or other lignocellulosic material based on sheet materials which is manufactured from fibers that are generally bonded together with a synthetic, thermosetting resin binder. Other agents can also be added during or after manufacture to modify particular properties of the panels such as water or fire resistance. It is typically supplied sanded in thickness of 12mm, and with a density of 750 $kg/m^3$. The moisture content (MC) for the board is at average of 8% to 10%. In this particular experiment, the MDF used is made from Rubberwood, with the dimension of 4 x 8 foot. Liquid Urea Formaldehyde (UF) is use as a resin binder and other chemical additives are unknown due to the company secret ingredient. The board is taken from the Golden Hope MDF at Nilai, Negeri Sembilan. The resources of Rubberwood supply can be obtain around Peninsular Malaysia.

Experiments with tungsten carbide rubbed on a rotating medium density fiberboard (MDF) disk were undertaken to provide additional information on tool wear mechanisms for machining dry wood and wood products such as MDF.

The chemical degradation of the tool material is at least a two-stage process when machining MDF. At relatively low temperatures, MDF decomposed to release sulfur containing vapors and liquids that will react with the tool material itself. At higher tool temperatures, both the tool material and the grains are oxidized in air. Sulfidation and oxidation are evident as high temperatures corrosion/oxidation tool wear mechanisms when the tool material is in contact with MDF a high temperatures (Reid, et al., 1991).

## 1.6 Objective

Primarily, this study is to evaluate the pattern of wear between high speed steel and solid tungsten carbide. Their router bits are different in the materials, consideration as the length of the cutting distance under specific cutting circumstances are of prime importance. Router bits wear pattern on rubberwood MDF are also to be assessed. The second objective is to prove that solid tungsten carbide can withstand twice the edge worn compare to high speed steel.

# CHAPTER II

## 2.0 LITERATURE REVIEW

### 2.1 The Tool Wear

Tool wear studies by their nature demand some type of measurement of edge dulling. The change in cutting tool in use has generally been monitored in two ways:

a. By observing the changes in the edge geometry.

b. By observing changes in the forces acting during cutting.

These cutting test have typically been performed with a given tool and results compared with other materials or geometry or cutting conditions, (Klamecki, 1979). Describing tool wear requires study of the interaction between the tool and the work material in the machining environment. For example, Decena et al., (1974) compare the wear of high speed steel and stellite-tipped saw teeth. The following types of saw teeth were used:

i. High speed steel,

ii. Stellite-tipped,

iii. Alternately HSS and stellite-tipped.

Krhazev (1958) and Prokes (1961) measured edge roughness effects of wear. Unfortunately, the quality of a finished surface is a function of the intended use and so a universal measure of cutter wear based on this criterion does not appear to be feasible.

The more objective measures of changes in tool or process characteristics appear more useful and most of the studies characterize wear in this way.

Chardin and Froidure (1969) have used what appear to be the most useful and widely accepted methods of observing cutting edge wear. These are measuring edge recession, photographing tools before and after use, making casts of the tool edge, and observing readily apparent tool characteristics, e.g., color change. A simple measure of the change in cutting edge geometry is that utilized by Prusak (1957). He used an optical microscope to measure the width of the bright band of light reflected from the worn edge. More direct measure of the change in the cutting edge is the specification of the recession of the edge from its original position.

Edamatsu and Ihira (1957) characterized cutter blunting by projecting the profile of the worn edge and measuring form that to its original position. Grube and Alekseev (1961) indicate a linear relationship between tool edge recession and the length of cut for steel and carbide cutters. Barz and Breier (1971) used a dial indicator to measure edge recession, a valuable and easy-to-use method of quantifying the change in cutting tools due to use.

## 2.2 Edge Recession

Edge recession is, in general, nonuniform along the tool edge and usually some average value is specified. Another way of accounting for the nonuniformity of edge recession in tool blunting is to specify the projected area representing the recession of the edge. The edge recession on the clearance face of the cutting tool was photographed and a planimeter used to measure the area worn away (Neusser and Schall, 1970).

Bridges (1971) projected worn edges onto a grid and used the area of the projection representing tool wear as an abrasiveness index for particleboards. Stevens and Fairbanks (1977) have defined an abrasiveness index for particleboard based on the loss of weight of the knife during machining. This type of measurement seems to have gained little acceptance since that the edge profile has an overriding effect on tool performance and so the volume worn may be less important than the morphology of the worn edge. Cowling and McKenzie (1969) used a double intergeometry technique to measure tool edge radius for sharp tools.

Endersby (1956a) in an extensive work, characterizes blunt edge profiles as areas with constant radii and states that the arc length is a measure of tool wear since it is independent of the tool wedge angle β.

The edge is said to assume an initial radius, which may decrease with length of cut. It is reported that neither the tool angle nor the depth of cut substantially affects the worn edge geometry Alekseev (1957a). Borovikov (1691) indicates that tool clearance face wear produces the rounded edge typical of woodcutting tool wear.

Bier and Hanicke (1963) show the predominance of clearance face wear and Pahlitzsch and Jostmeier (1964a) discuss the development of a rounded cutting edge from the viewpoint of increasing clearance face wear. After an initial period of cutting, the edge recession pattern seems to remain the same with increasing length of cut.

## 2.3 Aided Mechanisms in Determining the Wear.

A basic problem is whether visual observation, aided by microscope or not, of worn cutting edges can yield unambiguous information as to the cause of the wear. For example, the use of scanning electron microscopes with their high magnification, resolution and depth of field capabilities has made it possible to observe the two major components of carbide cutters and to draw inferences about basic wear mechanisms which act on them.

Barring the possibility of observing the wearing of cutting tools during operation some deduction is necessary from the observation of worn tools to arrive at the wear mechanisms acting. Combinations of experimental and analytical techniques are probably been needed to make these deductive studies representative of reality. The degree of sophistication necessary to accomplish this end is still an open question (Klamecki, 1979).

A large body of work indicates that the gradual wearing of cutting tools edges result in a characteristics worn edge profile. Edge profiles are typically determined by direct or magnified visual observation. Pahlitzsch and Schluz (1975) describe the profile of worn edges as curves with increasing radius from the rake to the clearance angles, $\alpha$ and $\gamma$ respectively.

Pahlitzsch and Jostmeier (1965) and Pahlitzsch and Sommer (1966) use the volume of tool material worn away as a measure of wear. Volume is calculated from edge recession measurements, assuming that the worn edge can be described as a circular arc. McKenzie and Cowling (1969) state that in the early stages of abrasive wear the cutting edge tends to assume a characteristics shape and radius.

Pahlitzsch and Sandvoss (1970) studied the edge over the useful life of the tool and determined that as tool wear proceeds the edge radius remains essentially constant and the wear land along the clearance face increases in length. Pahlitzsch and Jostmeier (1964a) cut pine and poplar particleboard using carbide and HSS and again the characteristics worn edge profile appeared on both types of cutters. This typical proceed of a rounded edge joining with the rake and clearance angles are produced by tool wear was observed by Barz (1966) while using both steel and carbide tools. Similar wear profiles are reported for steel and carbide tools by Barz and Breier (1969).